Activity ~ Oxidation and reduction

This activity will help you to test your knowledge and understanding of redox reactions. Read the *Answer Back* article on Oxidation and Reduction at AS and A2 (Chemistry Review Vol. 11, No. 4, pp. 13-15) before you start.

1. Assign oxidation states to each element in the following examples:
(a) $HXeO_4^-$
(b) Mn_2O_7
(c) FeO_4^{2-}
(d) $[Co(en)_2Cl_2]^+$

(en is the ligand $H_2N\text{-}CH_2CH_2\text{-}NH_2$: do not assign oxidation states to this).

2. Balance the following equation using oxidation state changes:

$$Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) \rightarrow Fe^{3+}(aq) + Cr^{3+}(aq)$$

3. Construct a full equation for the reaction between W^{3+} and MnO_4^- using the half equations below:

$$WO_4^{2-}(aq) + 3e^- + 8H^+(aq) \rightarrow W^{3+}(aq) + 4H_2O(l)$$

$$MnO_4^-(aq) + 5e^- + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

4. Split the following equation into two half equations:

$$3Tl^+(aq) + BrO_3^-(aq) + 6H^+(aq) \rightarrow 3Tl^{3+}(aq) + Br^-(aq) + 3H_2O(l)$$

5. (a) 'The standard electrode potential for $Cu^{2+}(aq)/Cu(s)$ is +0.34 V'. What do you understand by this?

(b) Draw and fully label a diagram of the apparatus that you would use to measure $E^\ominus$ for the $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ reaction.

(c) What is the difference between the electromotive force (EMF) and the potential difference (pd) of a cell?

(d) What type of voltmeter have you used in your apparatus? Why do you need this type?

6. Draw the apparatus for the iron half cell that you would use to measure $E^\ominus$ for the $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ reaction.

7.

	$E^\ominus$ values:
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	$E^\ominus$ = -2.37 V
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	$E^\ominus$ = -0.76 V
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$	$E^\ominus$ = -0.40 V
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	$E^\ominus$ = -0.25 V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	$E^\ominus$ = +0.34 V
$Br_2(aq) + 2e^- \rightarrow 2Br^-(aq)$	$E^\ominus$ = +1.09 V
$Cl_2(aq) + 2e^- \rightarrow 2Cl^-(aq)$	$E^\ominus$ = +1.36 V
$MnO_4^-(aq) + 5e^- + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l)$	$E^\ominus$ = +1.51 V

(a) Calculate the $E^\ominus_{cell}$ values for the following cells using the $E^\ominus$ values in the table. State which electrode is positive in each case.

(i) $Cd(s)/Cd^{2+}(aq)$ with $Ni^{2+}(aq)/Ni(s)$
(ii) $Cu(s)/Cu^{2+}(aq)$ with $Mg^{2+}(aq)/Mg(s)$

(b) The $E^\ominus_{cell}$ for a $Cu(s)/Cu^{2+}(aq)$ with $Ag^{+}(aq)/Ag(s)$ cell is 0.46 V, with the Ag electrode positive. Calculate $E^\ominus$ for $Ag^{+}(aq)/Ag(s)$.

(c) What would happen to the $E^\ominus_{cell}$ value for the $Cu(s)/Cu^{2+}(aq)$ with $Ag^{+}(aq)/Ag(s)$ cell if $Br^{-}(aq)$ was added to the silver half cell? Explain your answer **in full**.

(d) What would happen if the $Cu(s)/Cu^{2+}(aq)$ with $Ag^{+}(aq)/Ag(s)$ cell were short circuited? (i.e. What is the "cell reaction"?).

(e) Use the $E^\ominus$ values in the table to predict if you would expect nickel to displace metallic copper from a solution of copper ions.

(f) You can make Cl_2 by the oxidation of Cl^{-}. What oxidising agent, from the table, may be capable of doing this? Write an equation for the reaction.

(g) You can use $E^\ominus$ values to predict likely redox reactions. What two limitations are there to the predictions you make?

8. Photosynthesis is a complex redox process that plants use to make carbohydrate, $(CH_2O)_n$, and oxygen, O_2, from carbon dioxide, CO_2, and water, H_2O. The overall equation is:

$n CO_2 + n H_2O \rightarrow (CH_2O)_n + n O_2$ or, more simply:
$CO_2 + H_2O \rightarrow (CH_2O) + O_2$ reaction (i)

(a) Write the equation for reaction (i) as two half equations: one showing water being oxidised and the other showing carbon dioxide being reduced.

(b) Find out the part that chlorophyll *a* plays in photosynthesis?

9. Scientists are searching for a substance that will catalyse the decomposition of water to hydrogen and oxygen, using sunlight as the source of energy. They hope this will provide a relatively cheap source of hydrogen to use as a fuel.

Imagine the ion X^+ can make the decomposition happen. The overall equation for the decomposition of water is:

$H_2O(l) \rightarrow H_2(g) + \tfrac{1}{2}O_2(g)$

This splits into the two half equations (the *E* values are at pH7):

$2H^+(aq) + 2e^- \rightarrow H_2(g)$ E = -0.42 V reaction (ii)

$\tfrac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O(l)$ E = +0.81 V reaction (iii)

X^+ can oxidise water by taking electrons away — giving $O_2(g)$, $2H^+(aq)$ and X. When X absorbs radiation its electrons move to a higher energy level, giving the excited state X*. X* gives an electron to the $H^+(aq)$, forming $H_2(g)$ and regenerating the original X^+ ion.

(a) What type of radiation must X^+ be able to absorb for this process to be workable?

(b) Draw out an $E^\ominus$ chart showing the positions of reactions (ii) and (iii).

Show on the chart where the $E^\ominus$ values for the following reactions must be:
$X^+ + e^- = X$
$X^+ + e^- = X^*$